09-07-00

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PATENT
Docket No. 28503.20058.00
Express Mail Label No. EL591115049US
Client Reference 6TM-98S1026P1

CERTIFICATE OF MAILING BY "EXPRESS MAIL"

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Marco Jimenez

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the application of:	Examiner: Not Assigned
SUGIYAMA, et al.	Group Art Unit: Not Assigned
Serial No.: To Be Assigned	
Filing Date: Herewith	
For: PROCESS APPARATUS	

TRANSMITTAL FOR CONTINUATION APPLICATION UNDER 37 CFR 1.53(b)

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Transmitted herewith for filing is a continuation application pursuant to 37 CFR §1.53(b), of PCT/JP99/01055, filed March 4, 1999.

Enclosed are:

1. 32 pages of specification, including 11 claims;
2. 8 Sheets of formal drawings;
3. Certified copies of JP application serial no. 10-073433, filed March 6, 1998 and JP application serial no. 10-179616, filed June 11, 1998, from which priority is claimed.

4. Information Disclosure Statement and Form 1449 citing 6 references;

5. An Associate Power of Attorney;

6. A Declaration and Power of Attorney (4 pages);

7. An Assignment (2 pages);

8. A copy of the International Search Report and cited references;

9. A copy of the Preliminary Examination report and cited references;

10. Address all future communications to:

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11. Return Postcard is enclosed.

12. The filing fee has been calculated as follows:

FOR	NUMBER FILED	NUMBER EXTRA	RATE	CALCULA-TIONS
TOTAL CLAIMS	11- 20 =	0	x $18.00	$0
INDEPENDENT CLAIMS	2- 3 =	0	x $78.00	$0
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$0
			BASIC FEE	$690.00
		TOTAL OF ABOVE CALCULATIONS =		$690.00
Reduction by 1/2 for filing by small entity (Note 37 C.F.R. §§ 1.9, 1.27, 1.28). If applicable, verified statement must be attached.				$0
Recordation Fee				$40.00
			TOTAL =	$730.00

13. ☒ A check in the amount of $ 690.00 is attached for filing fee.

14. ☒ A check in the amount of $ 40.00 is attached for recordation fee.

15. ☒ Charge $ to **Deposit Account No. 03-1952** referencing docket no. 28503.20058.00. The Assistant Commissioner is hereby authorized to charge any fees under 37 C.F.R. §§ 1.16, 1.17, and 1.21 that may be required by this transmittal, or to credit any overpayment, to **Deposit Account No. 03-1952**. Applicant(s) hereby petitions for any required relief including extensions of time and authorizes the Assistant Commissioner to charge the cost of such petitions and/or other fees or to credit any overpayment to **Deposit Account No. 03-1952** referencing docket no. 28503.20058.00 . A duplicate copy of this transmittal is enclosed, for that purpose.

Respectfully submitted,

Dated: September 6, 2000

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TITLE OF THE INVENTION

PROCESS APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a Continuation of Application PCT/JP99/01055, filed March 4, 1999.

This application is based upon and claims the benefit of priority from the prior Japanese Patent Applications No. 10-073433, filed March 6, 1998; and No. 10-179616, June 11, 1998, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates to a process apparatus for performing a process, such as etching, on an object such as a semiconductor wafer.

A magnetron-type plasma process apparatus that is generally known comprises a gas-tight process vessel, an upper electrode provided in the vessel, a lower electrode provided in the vessel and opposing the upper electrode, and a magnet surrounding a plasma region provided between the upper and lower electrodes.

To perform a plasma process on an object by the use of such a magnetron-type plasma process apparatus, the object is mounted on the lower electrode. Then, the process gas is introduced into the process vessel. The process vessel is evacuated, whereby a low-pressure atmosphere is maintained in the vessel. Thereafter, high-frequency power is supplied to the lower

electrode, thereby generating plasma in the process vessel.

Generally, a plasma process apparatus of this type has a baffle plate, which partitions the process vessel into a process chamber and an exhaust passage. An object to be processed is placed in the process chamber. The exhaust passage communicates with an evacuation mechanism. The baffle plate is provided between the side of the lower electrode and the inner surface of the process vessel and surrounds the lower electrode. The baffle plate has a plurality of slits that extend in the radial direction, connecting the process chamber and the exhaust passage. (The chamber and the passage communicate with each other through these slits.) Thus, the baffle plate partitions the plasma region while the process is undergoing. This increases the density of plasma in the process chamber. Further, the conductance between the process chamber and the exhaust passage is maintained in a prescribed condition since the gas is guided from the chamber into the passage through the slits. Thus, the gas can be exhausted from the process chamber in a stable condition.

The baffle plate has the function of holding the reaction product made by the process, thus reducing the amount in which the reduction product flows into the exhaust passage. The reaction product deposits on that

surface of the baffle plate which is exposed to the process chamber (i.e., the surface of the plate facing the chamber). The amount of deposition is proportional to the time of process. If the product deposits on the rims of the slits though which the gas flows from the process chamber, the slits will become narrower. Consequently, the pressure in the process chamber will rise. This impairs the uniformity of etching in the plane of the object (i.e., in-plane uniformity) or decrease the etching rate. To prevent such undesirable events, the maintenance of the baffle plate is effected at regular intervals, by either washing the plate or replacing it with a new one. If the process generates deposit in large quantities, however, the maintenance must be carried out more frequently. In this case, the throughput of the process will decrease.

BRIEF SUMMARY OF THE INVENTION

The object of the invention is to provide a novel, improved process apparatus in which the slits of the baffle plate are hardly narrowed with deposit on the chamber side, an atmosphere of a prescribed pressure can therefore be maintained in the process chamber for a long time (that is, the process time can be lengthened without changing the process conditions), and the maintenance cycle of the baffle plate can be thereby extended to enhance the throughput of the process.

To attain the object, a process apparatus

according to the present invention includes an airtight process vessel, an exhaust system for exhausting gas from the process vessel, and a baffle plate for partitioning the process vessel into a process chamber for processing an object and an exhaust passage communicating with the exhaust system. The baffle plate has a plurality of slits through which the process chamber and the exhaust passage communicate with each other, and each of the slits has a tapered surface on an inner surface toward the process chamber, the tapered surface being formed to not less than 1/4 of a depth of the slit.

In particular, when the tapered surface is not less than 1/2 of the depth of the slit, it is preferable that angle θ between the tapered surface and a perpendicular crossing an open end of the slit at right angles fall within a range from 5° to 30° ($5^\circ \leqq \theta \leqq 30^\circ$).

When each slit has an enlarged opening facing the exhaust passage, extending from an opening rim of the slit, which faces the exhaust passage, toward the process chamber, and having an inside diameter which is larger than the minimum inside diameter of a process-chamber-side portion of the slit on which the tapered surface is formed, it is preferable that the tapered surface and the enlarged opening be each formed to 1/4 to 1/2 of the depth of the slit and angle θ between the

tapered surface and a perpendicular crossing an open end of the slit at right angles fall within a range from 30° to 60° (30° $\leqq \theta \leqq$ 60°). In this case, preferably, width W1 of an opening of the slit, which faces the process chamber, and width W2 of an opening of the slit, which faces the exhaust passage, are set so as to satisfy a condition of $1 \leqq W2/W1 \leqq 1.4$.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a sectional view schematically showing an etching apparatus that is an embodiment of this invention;

FIG. 2 is a magnified sectional view showing the edge of the lower electrode incorporated in the etching

apparatus;

FIG. 3 is a plan view of the baffle plate provided in the etching apparatus;

FIG. 4A is a magnified plan view of that side of the baffle plate which is exposed to the process chamber;

FIG. 4B is a magnified plan view of that side of the baffle plate which is exposed to the exhaust passage;

FIG. 4C is a sectional view, taken along line 4C-4C in FIG. 4A;

FIG. 5 is a sectional view illustrating the condition in which deposit lies on the baffle plate of FIG. 3;

FIG. 6 is a sectional view showing the condition in which deposit lies on a conventional baffle plate;

FIG. 7 is a graph representing how the pressure changed with process time during the experiments conducted in a process chamber partitioned by the baffle plate of FIG. 3 and conducted in a process chamber partitioned by the conventional baffle plate;

FIG. 8 is a graph illustrating how the etching rate changed with process time during the experiments conducted in a process chamber partitioned by the baffle plate of FIG. 3 and conducted in a process chamber partitioned by the conventional baffle plate;

FIG. 9 is a graph showing how the uniformity of

etching in the plane of an object changed with process time during the experiments conducted in a process chamber partitioned by the baffle plate of FIG. 3 and conducted in a process chamber partitioned by the conventional baffle plate;

FIG. 10A is a magnified plan view depicting that surface of a modification of the baffle plate shown in FIG. 3, which is exposed to the process chamber;

FIG. 10B is a magnified plan view showing that surface of the modification of the baffle plate shown in FIG. 3, which is exposed to the exhaust passage; and

FIG. 10C is a sectional view taken along line 10C-10C in FIG. 10;

FIG. 11 is a plan view showing a baffle plate having slits of a modified shape.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will now be described, with reference to the accompanying drawings.

FIG. 1 shows a magnetron-type plasma etching apparatus that is a process apparatus according to the present invention. As shown in FIG. 1, the etching apparatus 100 has a process vessel 102 made of aluminum and connected to the ground. An oxide aluminum film has been formed on the process vessel 102 by means of, for example, anodic oxidation. A lower electrode 104 is arranged in the process vessel 102. The lower electrode 104 serves as a susceptor that has a mounting

surface on which an object to be processed, e.g., a semiconductor wafer W (hereinafter referred to as "wafer"), may be mounted. As FIGS. 1 and 2 show, the lower electrode 104 is covered, except for the mounting surface, with an insulating member 105 made of, for example, ceramics, and a conductive member 107 made of, for example, aluminum. The lower electrode 104 can be moved up and down as lifting shafts 106 are driven.

Bellows 109 made of, for example, stainless steel are provided between the conductive member 107 and the process vessel 102. The conductive member 107 and process vessel 102 contact the bellows 109, with no aluminum film interposed between them and the bellows 109 (or with an aluminum film removed). Therefore, the conductive member 107 is connected to the ground by the bellows 109 and the process vessel 102. A bellows cover 111 is provided, surrounding the conductive member 107 and bellows 109. As shown in FIG. 1, an electrostatic chuck 110 connected to a high-voltage DC power supply 108 is provided on the mounting surface of the lower electrode 104. An insulating focus ring 112 is arranged, surrounding the electrostatic chuck 110. A high-frequency power supply 118 for outputting high-frequency power is connected to a matching device 116, which in turn is connected to the lower electrode 104.

An upper electrode 126 is provided on the inner surface of the process vessel 102, which opposes the

mounting surface of the lower electrode 104. The upper electrode 126 has a number of gas outlet holes 126a. The gas outlet holes 126a communicate with a gas-supplying source 150 that supplies process gas. The process gas supplied from the gas-supplying source 150 is therefore introduced into a process chamber 122 through the gas outlet holes 126a. An exhaust pipe 128 is connected, at one end, to a lower port of the process vessel 102 and, at the other end, to an evacuation mechanism 152. A magnet 130 is arranged outside the process vessel 102, for confining plasma generated between the lower electrode 104 and the upper electrode 126.

As shown in FIGS. 1 and 2, a baffle plate 120 is arranged beside the lower electrode 104, partitioning the interior of the process vessel into the process chamber 122 for processing the wafer and the exhaust passage 124 communicating with the exhaust pipe 128. The baffle plate 120 is located between the circumferential surface of the lower electrode 104 and the inner surface of the process vessel 102 and surrounds the lower electrode 104. More specifically, the baffle plate 120 is clamped between the focus ring 112 and the conductive member 107. As shown in FIG. 2, the plate 120 is secured to the top of the conductive member 107 by electrically conductive screws 121.

Like the conventional baffle plate, the baffle

plate 120 is made of electrically conductive material such as aluminum and has a surface oxidized by anodic oxidation. The baffle plate 120 and the conductive member 107 contact each other, with no aluminum oxide film interposed between them. In other words, the aluminum oxide film has been removed from that part of the plate 120 which contacts the conductive member 107. The baffle plate 120 is therefore connected to the ground by the conductive member 107, bellows 109 and process vessel 102 and remains at almost the same potential (ground potential) as the inner wall of the process vessel 102. As a result, the baffle plate 120 and the inner wall of the vessel 102, which is located above the baffle plate 120, function as counter electrodes of the lower electrode 104. Plasma can, therefore, be confined in a space above the baffle plate 120, that is, within the process chamber 122.

As FIG. 3 shows in detail, the baffle plate 120 is shaped almost like a ring. The plate 120 has a thickness that falls within the range from 1 mm to 20 mm. In the present embodiment, the plate 120 is 3 mm thick. The baffle plate 120 has a plurality of slits, e.g., 360 slits 120a arranged on the entire circumferential surface of the plate 120 in order to cause the process chamber 122 and exhaust passage 124 to communicate with each other when the baffle plate 120 is mounted on the lower electrode 104.

More precisely, the slits 120a extend in radial directions of the baffle plate 120. The number of slits 120a can be changed to any value, ranging from 180 to 540, in accordance with the process apparatus to which the baffle plate 120 is applied.

The slits 120a (arranged in the radial directions of the baffle plate 120) have a length that falls within the range from 35 mm to 45 mm. In the present embodiment, the length is set to 41 mm. The slits 120a have a width that falls within the range from 0.5 mm to 2.5 mm. In the present embodiment, the width is set to 1.6 mm. The area of the opening of each slit 120a, which faces the process chamber 122, is 25% to 75% of that of the surface (top) of the baffle plate 120 which faces the chamber 122. In the present embodiment, it is set to 54%.

As FIG. 1 illustrates, when the baffle plate 120 is arranged between the side of the lower electrode 104 and the inner surface of the process vessel 102, only the minimum gap, which does not prevent the lower electrode 104 from moving up and down, is formed between the outer surface of the baffle plate 120 and the inner surface of the process vessel 102. The gas in the process chamber 122 is therefore exhausted from the exhaust passage 124 into an exhaust pipe 128 only through the slits 120a of the baffle plate 120.

As shown in FIGS. 3 and 4A to 4C, each of the

slits 120a has a tapered surface 132 toward the process chamber 122. The tapered surface 132 extends in the radial direction of the baffle plate 120 on either side of the slit 120a and inclines from the rim of the slit 120a, which faces the process chamber 122, toward the exhaust passage 124 in which direction the opening of the slit 120a is narrowed. As FIG. 4C shows, the distance (hereinafter referred to as "taper depth") h between an open end 132a of the slit 120a, which opposes the process chamber 122, and a region 132b surrounded by the lower rim 132c of the tapered surface 132, is substantially not less than half the distance (hereinafter referred to as "slit depth") H between the open end 132a and the other open end 134 of the slit 120a, which opposes the exhaust passage 124. In the present embodiment, the taper depth h is set to three fourths of the slit depth H. The angle (hereinafter referred to as "taper angle") θ between the tapered surface 132 and a perpendicular 136 (a line crossing the open ends 132a and 134 at right angles) falls within the range from 5° to 30° ($5^\circ \leqq \theta \leqq 30^\circ$). In the present embodiment, the angle θ is set to 10°.

FIG. 6 shows an example of deposit a deposited on a conventional baffle plate X. As shown, in the baffle plate X, each slit S has a tapered surface T toward the process chamber, and the tapered surface T is formed by chamfering in order to prevent the rim of the slit S

from being damaged due to a plasma atmosphere. In this case, the taper depth h of the taper surface T is about one sixth of the slit depth H, while the taper angle θ of the tapered surface T is 45°. Therefore, the deposit a greatly juts into the slit S and the inside diameter R1 of the slit S is shortened in a short time (FIG. 6 shows the condition in which the inside diameter R1 of the slit S is decreased to R2 by the deposit a). The flow rate of gas passing through the slit S lowers in a relatively short time, and the pressure in the process chamber rises in a relatively short time. In other words, the uniformity of etching in the plane of a wafer W (in-plane uniformity) deteriorates in a relatively short time and the etching rate decreases in a short time, too. Consequently, the maintenance of the baffle plate X must be carried out more frequently, and the throughput of the process will decrease.

FIG. 5 shows an example of a deposit a deposited on the baffle plate 120 of the present embodiment. If, as shown, the taper depth h is not less than half the slit depth H and the taper angle θ ranges from 5° to 30° ($5° \leqq \theta \leqq 30°$), the deposit a is deposited gradually from the top of the tapered surface 132. The opening of the slit 120a, which faces the process chamber 122, is hardly narrowed by the deposit a, and it takes a considerably long time to make the inside

diameter of the slit 120a smaller than the prescribed value R1. In other words, the gas in the process chamber 122 is allowed to pass through the slit 120a without resistance for a long time, and a given pressure is maintained in the process chamber 122 for a long time (the process time can be lengthened more than the conventional one without changing any process conditions). Consequently, the uniformity of etching in the plane of the wafer W (in-plane uniformity) is maintained for a long time, as is the high etching rate. The maintenance cycle of the baffle plate 120 can be extended to enhance the throughput of the process (by securing a long time for which the baffle plate 120 can be processed continuously without maintenance or exchange). The following are experimental data to support the advantages of the baffle plate 120 of the present invention.

EXPERIMENTAL DATA

The experiment was performed under the same process (etching) conditions when two baffle plates to be compared were attached separately to the same plasma etching apparatus 100 (see FIG. 1).

[Objects to be Compared]

* Baffle plate 120 of the present invention (see FIGS. 3 and 4)

Taper depth h ... 3/4 of slit depth H

Taper angle θ ... 10°

* Conventional baffle plate X (see FIG. 6)

Taper depth h ... 1/6 of slit depth H

Taper angle θ ... 45°

Note: The conventional baffle plate X is the same as the baffle plate 120 except for taper depth h and taper angle θ.

[Process Conditions]

* Object to be processed: 200 mm-diameter semiconductor wafer W made of silicon (Si), on the surface of which a silicon oxide film (SiO_2 film) to be etched is formed.

* Etching gas: a mixture of C_4F_8 having a flow rate of 16 sccm, CO having a flow rate of 300 sccm, and Ar having a flow rate of 400 sccm.

* Temperature of mounting surface of lower electrode 104: 20℃

* Temperature of inner surface of process vessel 102 including upper electrode 126: 60℃

* High-frequency power applied to lower electrode 104: 13.56 MHz, 1700W

<u>Experimental Data 1</u>

FIG. 7 shows variations in pressure in process chamber 122 with process time.

(Analysis)

In the process of etching a silicon oxide film using C_4F_8, CO and Ar, both the etching rate and in-plane uniformity decrease when the pressure atmosphere in the process chamber 122 is 65 mTorr or

higher in substance. The time required until the pressure atmosphere reaches 65 mTorr therefore corresponds to continuous process time.

As shown, when the baffle plate 120 of the present invention (present embodiment) was used, the pressure atmosphere in the process chamber 122 arrived at 65 mTorr in about 85 hours. In contrast, when the conventional baffle plate X was employed, the pressure atmosphere arrived at 65 mTorr in about 40 hours.

Though not shown, even when only the taper depth h was 1/2 and 1/1 of the slit depth H with the taper angle θ of the tapered surface 132 at 10°, the process time required until the pressure atmosphere in the process chamber 122 reached 65 mTorr, was 70 hours or more in either case. Furthermore, even when only the taper angle θ was set at 5°, 10°, 15°, 20°, 25° and 30° with the taper depth h of the tapered surface 132 3/4 of the slit depth H, the process time required until the pressure atmosphere in the process chamber 122 reached 65 mTorr, was 60 hours or more in either case.

(Conclusion)

If, as the above results, the taper depth h of the tapered surface 132 is set properly within the range of 1/2 to 1/1 of the slit depth H or the taper angle θ is set properly within the range of 5° to 30°, the continuous process time can be extended more greatly

than using the conventional baffle plate X. If, in particular, the baffle plate 120 is used, the continuous process time can be extended two or more times as long as that in the case of the conventional baffle plate.

Experimental Data 2

FIG. 8 shows variations in etching rate with process time.

(Analysis)

When the baffle plate 120 of the present invention (present embodiment) was used as shown, the etching process could be performed at a high etching rate of about 270 nm per minute if the process time did not exceed about 100 hours. In contrast, when the conventional baffle plate X was used, the etching process could be performed at the same etching rate as that of the present invention if the process time did not exceed about 40 hours; however, the etching rate lowered abruptly immediately after the process time exceeded 40 hours.

(Conclusion)

If the baffle plate 120 is used, a desired uniform etching rate can be achieved even after a lapse of process time which is two or more times as long as that in the case of the conventional baffle plate X.

Experimental Data 3

FIG. 9 shows variations in in-plane uniformity

with process time. Values of the in-plane uniformity were obtained from the following equation using the maximum and minimum values A and B of etching rates measured at a plurality of measurement points on the surface of the wafer W to be processed (including the center of the surface).

$$(\text{in-plane uniformity}) = \pm \{(A-B)/(A+B)\} \times 100 \ [\%]$$

As is evident from the above equation, the in-plane uniformity indicates variations in etching rate on the entire surface of the wafer W to be processed (percentage of the maximum values or the minimum values deviating from the average value). The smaller the value of the in-plane uniformity, the higher the uniformity.

(Analysis)

When the baffle plate 120 of the present invention (present embodiment) was used as shown, the in-plane uniformity of ±5% could be obtained if the process time did not exceed about 80 hours. In contrast, when the conventional baffle plate X was used, the same in-plane uniformity as that of the present invention could be obtained if the process time did not exceed about 20 hours; however, the value of the in-plane uniformity increased when the process time exceeded 20 hours and it increased abruptly immediately after the process time exceeded 40 hours.

(Conclusion)

If the baffle plate 120 is used, prescribed in-plane-uniformity can be achieved even after a lapse of process time which is four or more times as long as that in the case of the conventional baffle plate X.

As has been described above, in the baffle plate 120 of the etching apparatus 100 according to the present embodiment, the taper depth h of the tapered surface 132 is set not less than half the slit depth H and the taper angle θ falls within the range from 5° to 30° ($5° \leqq \theta \leqq 30°$). Since the depth of the taper surface 132 is considerably greater (1/2 or more of the slit depth H in substance), the area of the tapered surface can be enlarged more greatly than that of the conventional baffle plate X, keeping the conductance of the process chamber 122 and exhaust passage 124 in prescribed conditions. Since, moreover, the taper angle θ falls within the range from 5° to 30° ($5° \leqq \theta$ 30°), a deposit is formed effectively on the tapered surface 132.

Therefore, a deposit such as a reaction product is formed on the baffle plate 120 in sequence from the top of the tapered surface 132, and the openings of the slits 120a, which face the process chamber 122, are hardly narrowed by the deposit. For this reason, gas in the process chamber 122 can be caused to pass through the slits 120a for a long time without

resistance and a given process pressure is maintained in the process chamber 122 for a long time (it is possible to extend time required until a pressure atmosphere of the process chamber 122 increases due to clogging of the slits 120a). In other words, the process time can be extended longer than that in the prior art without changing process conditions. Consequently, as is evident from the above experimental data, the in-plane uniformity and etching rate of the wafer W can be maintained high for a long time, and the maintenance cycle of the baffle plate 120 can be extended more greatly than that in the prior art to improve the throughput of the process.

In the present embodiment, the inside diameter of each slit 120a is not increased but the slit 120a has a large tapered surface 132 with a given depth and angle which opposes the process chamber 122. Thus, the process time can be extended without exercising an influence on the conductance in the process chamber 122 and exhaust passage 124.

FIGS. 10A to 10C illustrate a modification to the baffle plate of the embodiment described above.

In a baffle plate 200 of the modification shown in FIGS. 10A to 10C, a plurality of slits 200a are arranged on the entire circumferential surface of the plate 200 in order to cause the process chamber 122 and exhaust passage 124 to communicate with each other when

the baffle plate 200 is mounted on the lower electrode 104. More specifically, the slits 200a extend in radial directions of the baffle plate 200. As shown in FIGS. 10A and 10C, each of the slits 200a has a tapered surface 202 toward the process chamber 122. As illustrated in FIGS. 10B and 10C, an enlarged opening 204 is provided toward the exhaust passage 124 of the slits 200a.

As FIGS. 10A and 10C illustrate, the tapered surface 202 extends in the radial direction of the baffle plate 200 on either side of the slit 200a and inclines from the rim of the slit 200a, which faces the process chamber 122, toward the exhaust passage 124 in which direction the opening of the slit 200a is narrowed. The distance between an open end 202a of the slit 200a, which opposes the process chamber 122, and a region 202b surrounded by the lower rim 202c of the tapered surface 202, i.e., the taper depth h1 is substantially 1/4 to 1/2 of the distance between the open end 202a and the other open end 204a of the slit 200a (enlarged opening 204), which opposes the exhaust passage 124, i.e., the slit depth H. In the present modification, the taper depth h1 is set to one third of the slit depth H. The angle between the tapered surface 202 and a perpendicular 206, i.e., the taper angle θ falls within the range from 30° to 60° ($30^\circ \leqq \theta \leqq 60^\circ$) in substance. In the present

modification, the angle θ is set to 45°.

As FIGS. 10B and 10C illustrate, the enlarged opening 204 is shaped almost like a trench and formed along the radial direction of the baffle plate 200 alongside the exhaust passage 124 of the slit 200a. The distance h2 between the open end 204a of the opening 204, which opposes the exhaust passage 124, and a region 204b surrounded by a bottom rim 204c of the opening 204 (hereinafter referred to as "enlarged opening depth") is 1/4 to 1/2 of the slit depth H in substance. Particularly, in the present modification, the distance h2 is set to 1/2 of the slit depth H. The area of the open end 204a of the enlarged opening 204 is set larger than that of the region 202b of the lower rim 202c of the tapered surface 202. Moreover, the width W1 of the slit 200a, which faces the process chamber 122, and the width W2 of the slit 200a, which faces the exhaust passage 124, are set so as to satisfy the condition of $1 \leqq W2/W1 \leqq 1.4$ in substance. Particularly, in the present modification, W2/W1 is set at 1.2.

That portion of the slit 200a with the tapered surface 202 which faces the process chamber 122 and that portion of the slit 200a with the enlarged opening 204 which faces the exhaust passage 124 communicate with each other through a passage 208 having the same section and size as those of the region 202b surrounded

by the lower rim 202c of the tapered surface 202.

The baffle plate 200 having the above-described structure was applied to the etching apparatus 100 shown in FIG. 1 and the wafer W (which is identical with that used in the above experiments) was processed by etching under the same process conditions as those of the above experiments. It was 60 hours or longer before the pressure atmosphere in the process chamber 122 reached 65 mTorr. Even when the same experiments were carried out by changing only the taper angle θ of the tapered surface to 30°, 40°, 50° and 60°, it was 60 hours or longer before the pressure atmosphere in the process chamber 122 reached 65 mTorr in each case. If, therefore, the taper angle θ of the tapered surface 202 is properly set within the range from 30° to 60° in substance in the baffle plate 200 having the enlarged opening 204, the continuous process time can be extended more greatly than using the conventional baffle plate X. Further, even when the same experiments were performed by changing only the value of W2/W1 to 1 and 1.4, it was 60 hours or longer before the pressure atmosphere in the process chamber 122 reached 65 mTorr in either case. If, therefore, W2/W1 is properly set within the range from 1 to 1.4 in substance in the baffle plate 200 having the enlarged opening 204, the continuous process time can be extended more greatly than using the conventional

baffle plate X.

As described above, in the baffle plate 200 according to the present modification, the taper depth h1 of the tapered surface 202 is 1/4 to 1/2 of the slit depth H and the taper angle θ falls within the range from 30° to 60° ($30° \leqq \theta \leqq 60°$). The depth of the tapered surface 202 is therefore considerably greater, the area of the tapered surface can be enlarged more greatly than that of the conventional baffle plate X, keeping the conductance of the process chamber 122 and exhaust passage 124 in prescribed conditions. Since, moreover, the taper angle θ falls within the range from 30° to 60° ($30° \leqq \theta \leqq 60°$), a deposit is formed effectively on the tapered surface 202.

Therefore, a deposit such as a reaction product is formed on the baffle plate 200 in sequence from the top of the tapered surface 202, and the openings of the slits 200a, which face the process chamber 122, are hardly narrowed by the deposit. For this reason, gas in the process chamber 122 can be caused to pass through the slits 200a for a long time without resistance and a given process pressure is maintained in the process chamber 122 for a long time. In other words, the process time can be extended longer than that in the prior art without changing process conditions. Consequently, the in-plane uniformity and etching rate of the wafer W can be maintained high for

a long time, and the maintenance cycle of the baffle plate 200 can be extended more greatly than that in the prior art to improve the throughput of the process.

In particular, the baffle plate 200 of the present modification has the enlarged opening 204 having a large opening area toward the exhaust passage 124 of the slit 200a and the depth h2 of the enlarged opening is set to 1/4 to 1/2 of the slit depth H in substance. Consequently, a small-diameter portion in the slit 200a on which a deposit is easily formed, can be decreased, and time can be extended further until the process chamber 122 increases in pressure. Since, in the present modification, the area of the open end 204a of the enlarged opening 204 is set larger than that of the region 202b surrounded by the lower rim 202c of the tapered surface 202, gas can be uniformly guided to the exhaust passage 124 through the slits 200 without any disturbance.

According to the present modification, the width W1 of the slit 200a, which faces the process chamber 122, and the width W2 of the slit 200a, which faces the exhaust passage 124, are set so as to satisfy the condition of $1 \leqq W2/W1 \leqq 1.4$ in substance. Therefore, time can be extended further until the opening of the slit 200a is narrowed by the deposit, without exercising an influence on the conductance in the process chamber 122 and exhaust passage 124.

In the present modification, that portion of the slit 200a with the tapered surface 202 which faces the process chamber 122 and that portion of the slit 200a with the enlarged opening 204 which faces the exhaust passage 124 communicate with each other through the passage 208 having the same section and size as those of the region 202b surrounded by the lower rim 202c of the tapered surface 202. The conductance in the process chamber 122 and exhaust passage 124 can thus be maintained in a desired condition even though the slit 200a is provided with the tapered surface 202 and enlarged opening 204.

The present invention is not limited to the foregoing embodiment and modification. It is needless to say that various changes and modifications can be made without departing from the scope of the subject matter of the present invention. In the above embodiment, the width of the slit 120a is constant on both the inner and outer sides of the baffle plate 120; however, it can be varied as shown in FIG. 11. In the example of FIG. 11, width W4 on the outer side is set greater than width W3 on the inner side. In the above embodiment and modification, corner portions are formed at the upper rim (opening rim) of the tapered surface 132 (202), the lower rim 132c (202c) of the tapered surface 132 (202), the bottom of the enlarged opening 204, and the open end 204a of the opening 204; however,

these corner portions can be chamfered. In the embodiment described above, the wafer is processed by etching by C_4F_8, CO and Ar. The present invention can be applied to another process apparatus such as a plasma CVD apparatus and a process of another object such as an LCD glass substrate.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A process apparatus including an airtight process vessel, an exhaust system for exhausting gas from the process vessel, and a baffle plate for partitioning the process vessel into a process chamber for processing an object and an exhaust passage communicating with the exhaust system,

wherein the baffle plate has a plurality of slits through which the process chamber and the exhaust passage communicate with each other;

each slit has a tapered surface on an inner surface toward the process chamber, the tapered surface being formed to not less than 1/4 of a depth of the slit; and

an angle θ between the tapered surface and a perpendicular crossing an open end of the slit at right angles falls within a range from 5° to 30° ($5^\circ \leqq \theta \leqq 30^\circ$).

2. The process apparatus according to claim 1, wherein the tapered surface is formed to not less than 1/2 of the depth of the slit.

3. The process apparatus according to claim 2, wherein the baffle plate is shaped like a ring, and the plurality of slits are arranged radially on an entire circumferential surface of the baffle plate.

4. The process apparatus according to claim 2, wherein each slit extends in a radial direction of the

baffle plate, and the tapered surface extends in the radial direction of the baffle plate on either side of the slit and inclines from an opening rim of the slit, which faces the process chamber, toward the exhaust passage in which direction the opening of the slit is narrowed.

5. A process apparatus including an airtight process vessel, an exhaust system for exhausting gas from the process vessel, and a baffle plate for partitioning the process vessel into a process chamber for processing an object and an exhaust passage communicating with the exhaust system,

wherein the baffle plate has a plurality of slits through which the process chamber and the exhaust passage communicate with each other;

each slit has a tapered surface on an inner surface toward the process chamber, the tapered surface being formed to not less than 1/4 of a depth of the slit; and

each slit has an enlarged opening facing the exhaust passage, the enlarged opening extending from an opening rim of the slit, which faces the exhaust passage, toward the process chamber and having an inside diameter which is larger than a minimum inside diameter of a process-chamber-side portion of the slit on which the tapered surface is formed.

6. The process apparatus according to claim 5,

wherein the tapered surface and the enlarged opening are each formed to 1/4 to 1/2 of the depth of the slit.

7. The process apparatus according to claim 5, wherein the baffle plate is shaped like a ring, and the plurality of slits are arranged radially on an entire circumferential surface of the baffle plate.

8. The process apparatus according to claim 5, wherein each slit extends in a radial direction of the baffle plate, and the tapered surface extends in the radial direction of the baffle plate on either side of the slit and inclines from an opening rim of the slit, which faces the process chamber, toward the exhaust passage in which direction the opening of the slit is narrowed.

9. The process apparatus according to claim 8, wherein the enlarged opening and the process-chamber-side portion of the slit where the tapered surface is formed communicate with each other through a passage having a same section and size as those of a region surrounded by an inner rim of the tapered surface.

10. The process apparatus according to claim 5, wherein an angle θ between the tapered surface and a perpendicular crossing an open end of the slit at right angles falls within a range from 30° to 60° ($30° \leqq \theta \leqq 60°$).

11. The process apparatus according to claim 5, wherein a width W1 of an opening of the slit, which

faces the process chamber, and a width W2 of an opening of the slit, which faces the exhaust passage, are set so as to satisfy a condition of $1 \leqq W2/W1 \leqq 1.4$.

ABSTRACT OF THE DISCLOSURE

The present invention provides a process apparatus including an airtight process vessel, an exhaust system for exhausting gas from the process vessel, and a baffle plate for partitioning the process vessel into a process chamber for processing an object and an exhaust passage communicating with the exhaust system, the baffle plate has a plurality of slits through which the process chamber and the exhaust passage communicate with each other, and each of the slits has a tapered surface on an inner surface toward the process chamber, the tapered surface corresponding to not less than 1/4 of a depth of the slit.

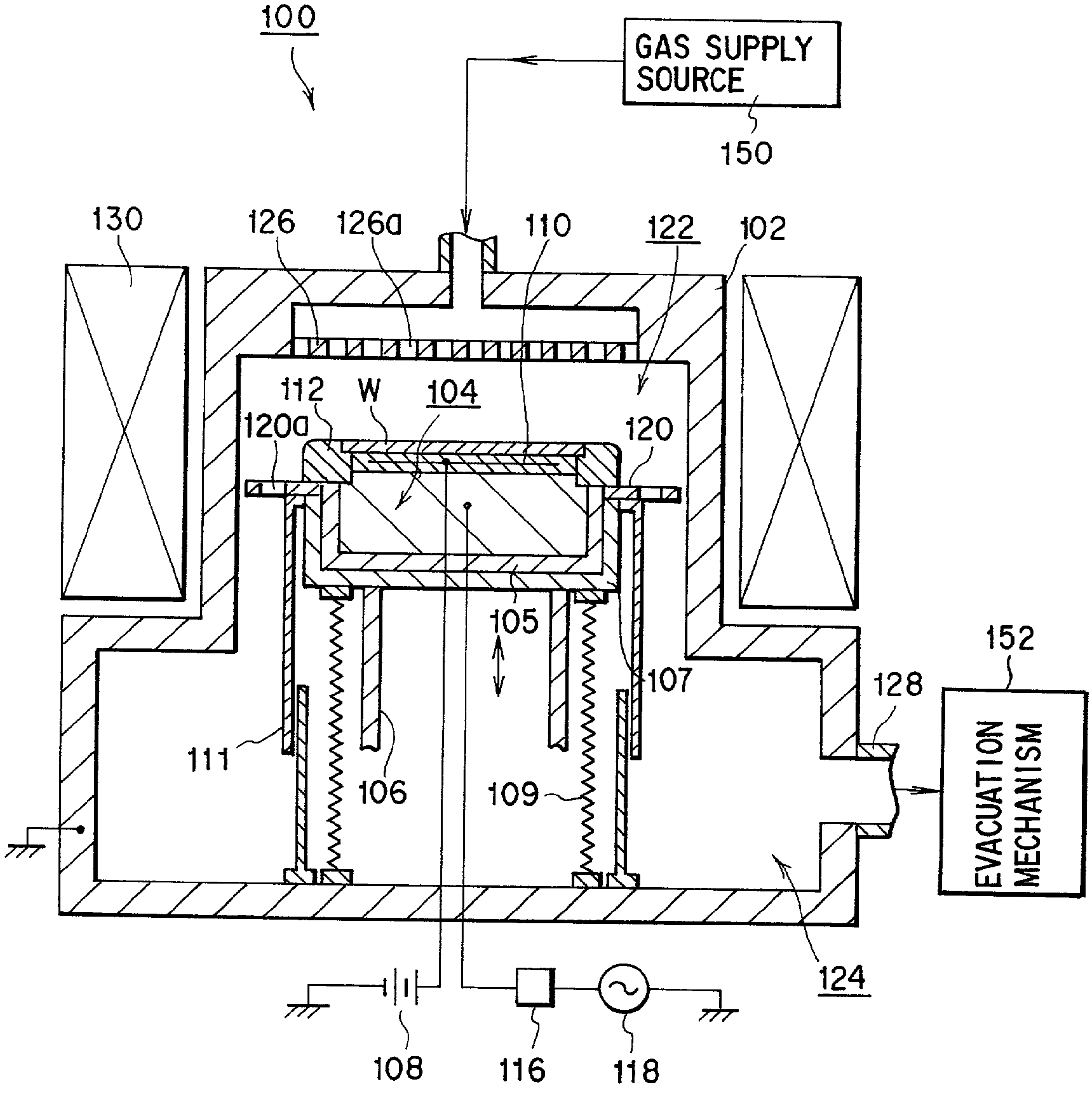
100
GAS SUPPLY SOURCE
150
130
126
126a
110
122
102
112
W
104
120a
120
105
107
152
128
111
106
109
EVACUATION MECHANISM
124
108
116
118

FIG. 1

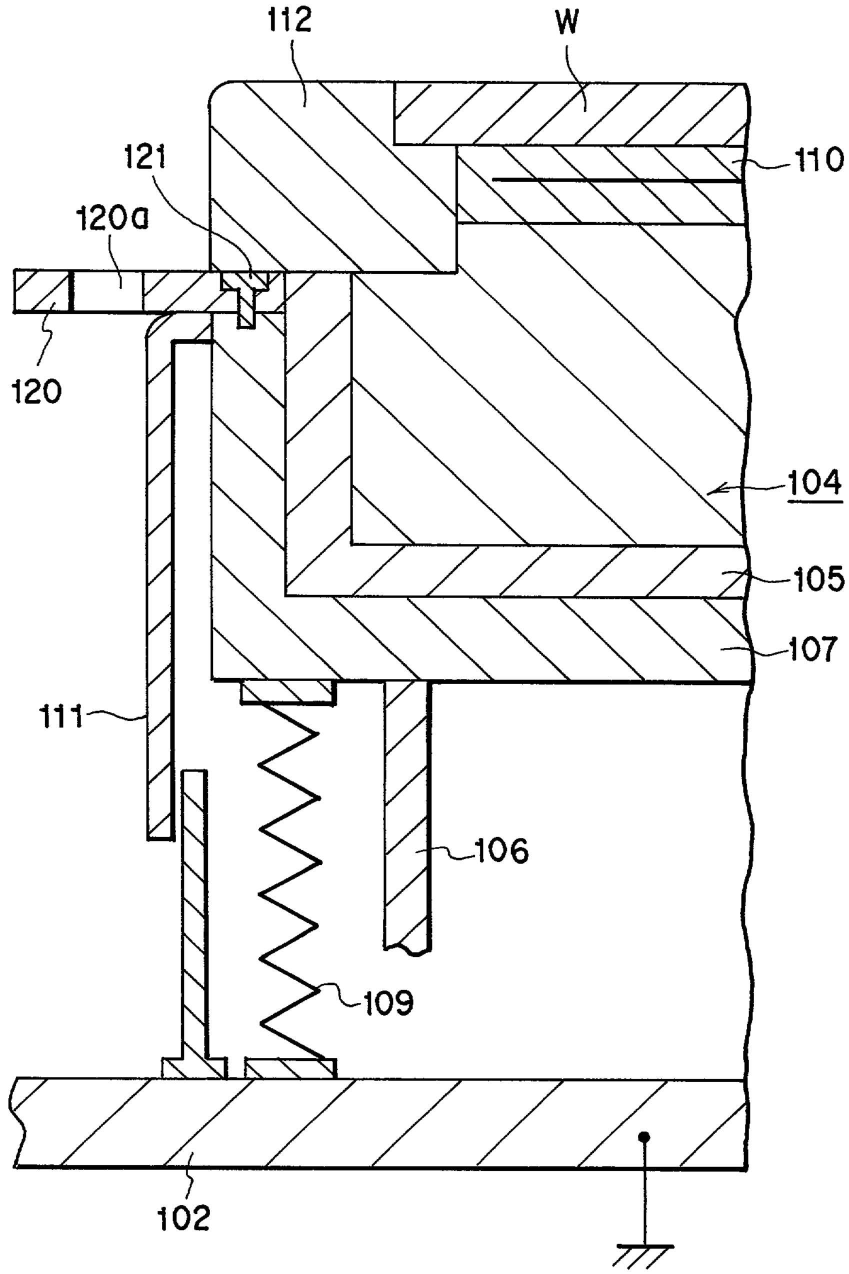

FIG.2

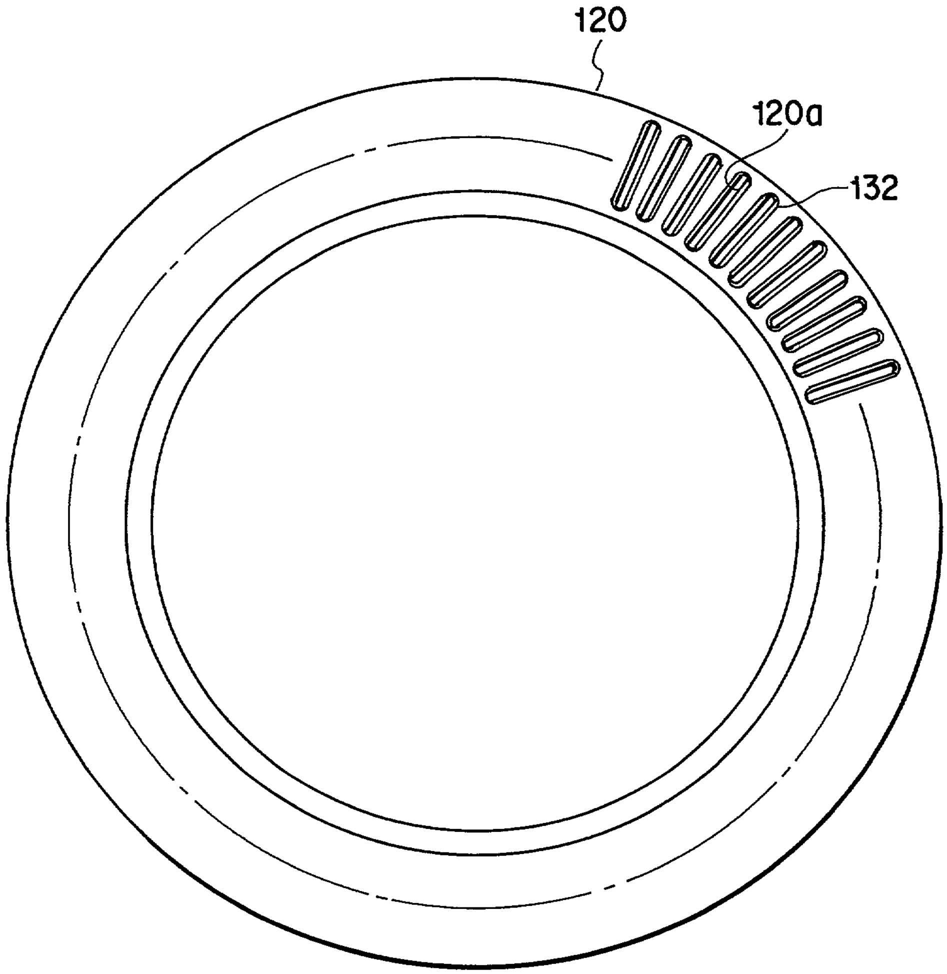

FIG.3

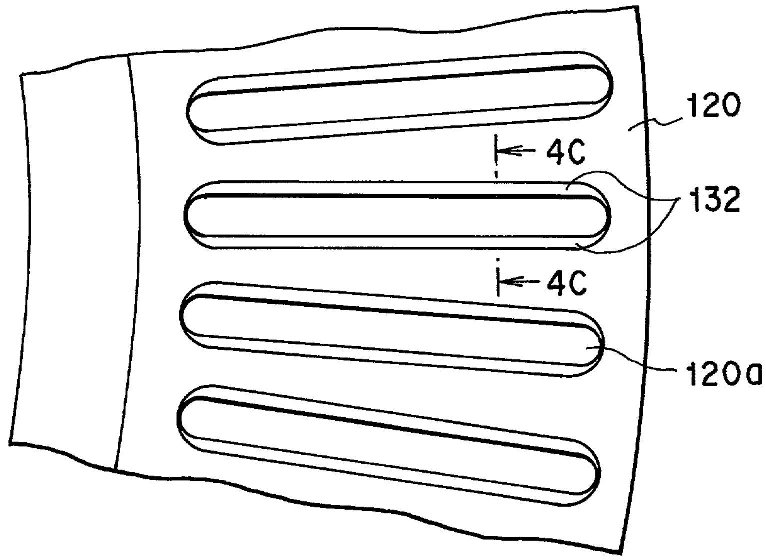

FIG.4A

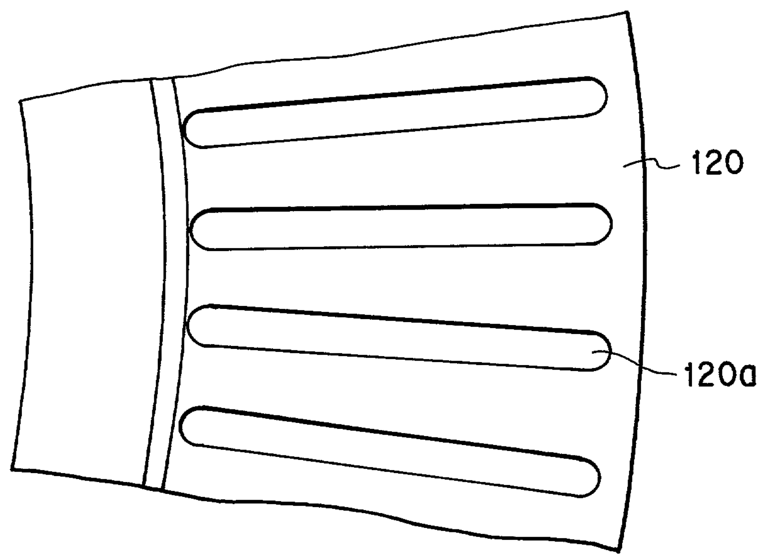

FIG.4B

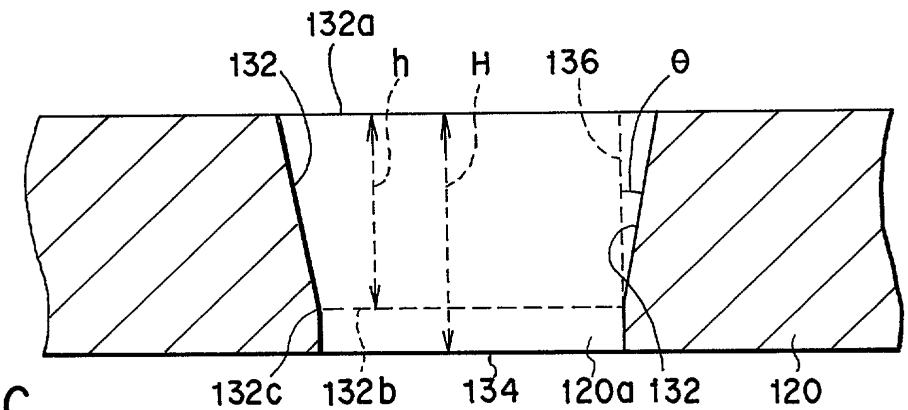

FIG.4C

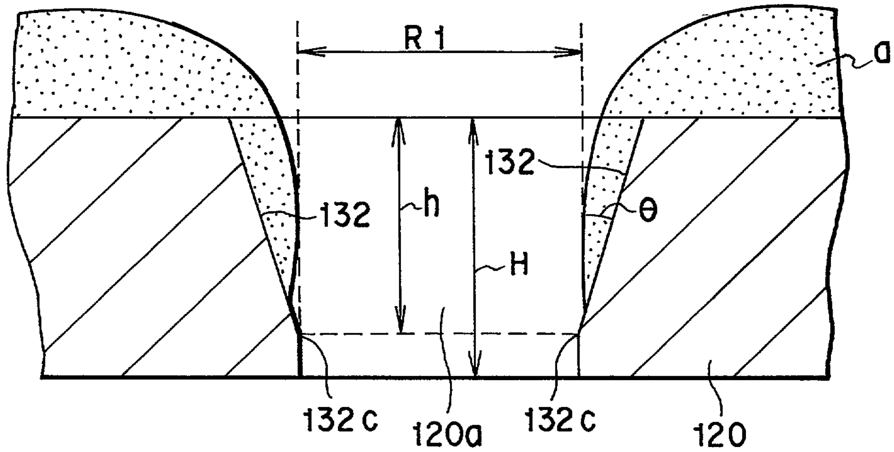

FIG.5

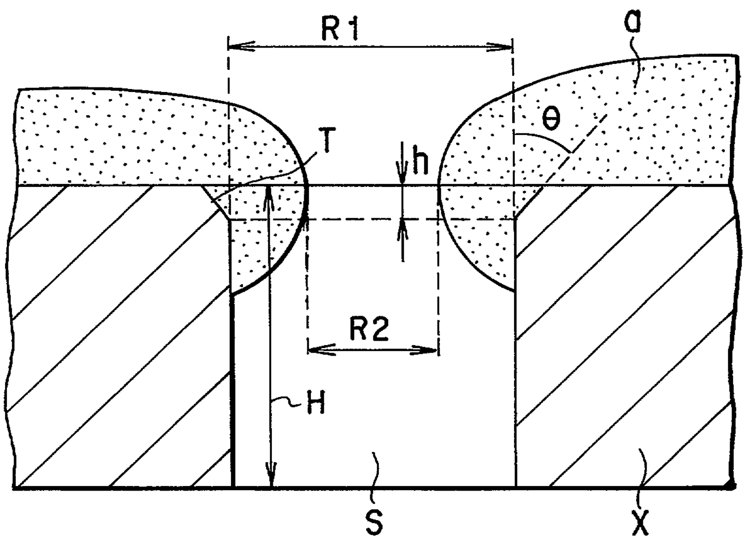

FIG.6 (PRIOR ART)

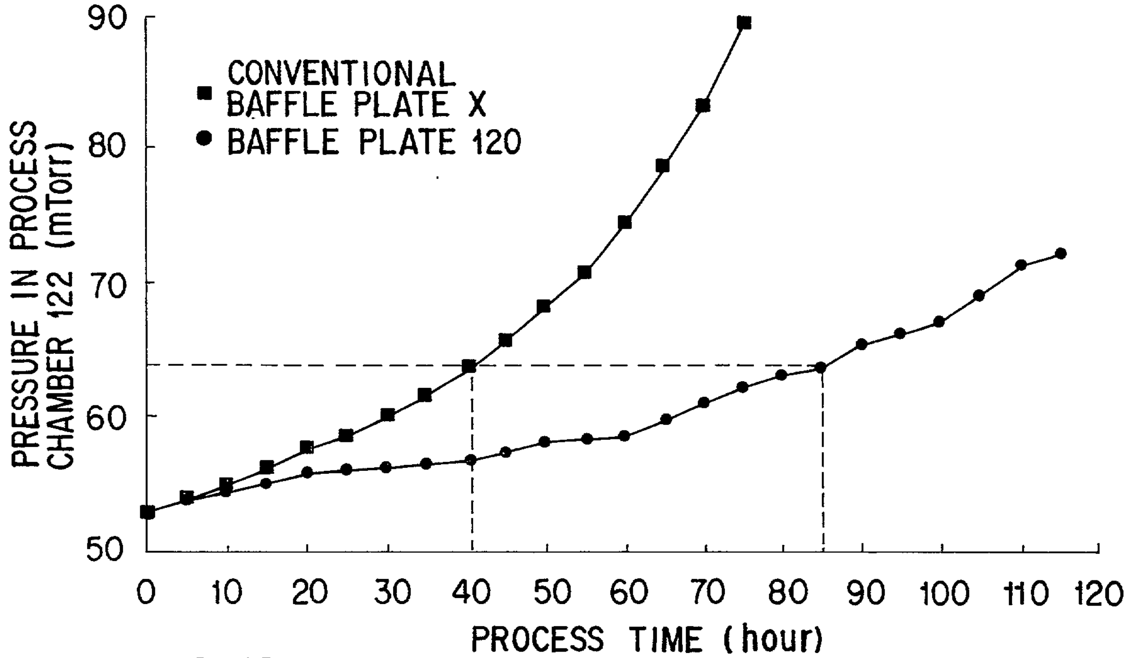
90
80
70
60
50
PRESSURE IN PROCESS CHAMBER 122 (mTorr)
CONVENTIONAL BAFFLE PLATE X
BAFFLE PLATE 120
0 10 20 30 40 50 60 70 80 90 100 110 120
PROCESS TIME (hour)

FIG.7

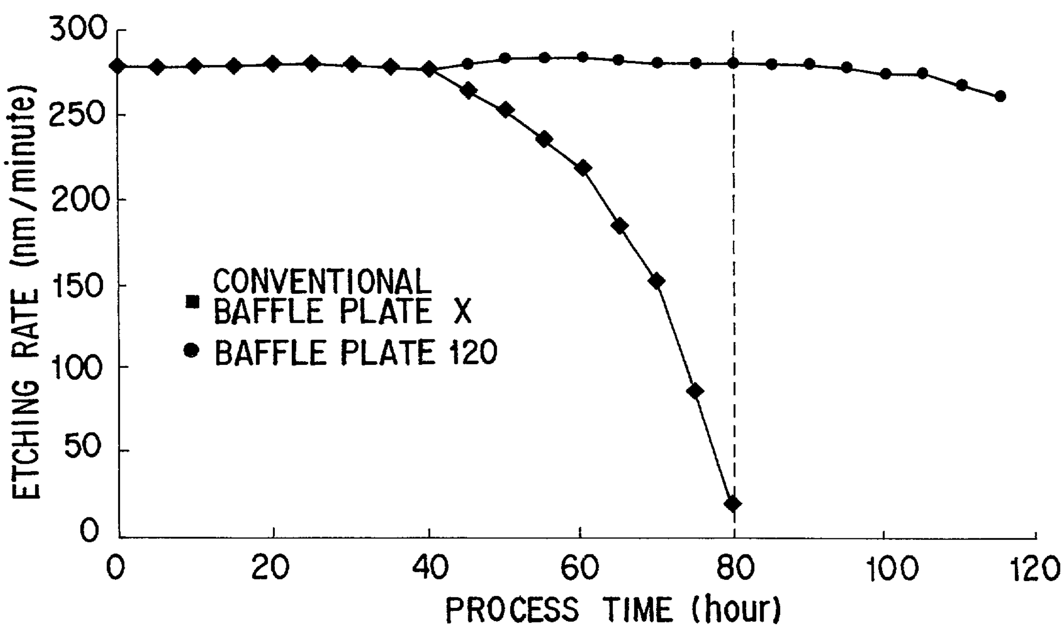
300
250
200
150
100
50
0
ETCHING RATE (nm/minute)
CONVENTIONAL BAFFLE PLATE X
BAFFLE PLATE 120
0 20 40 60 80 100 120
PROCESS TIME (hour)

FIG.8

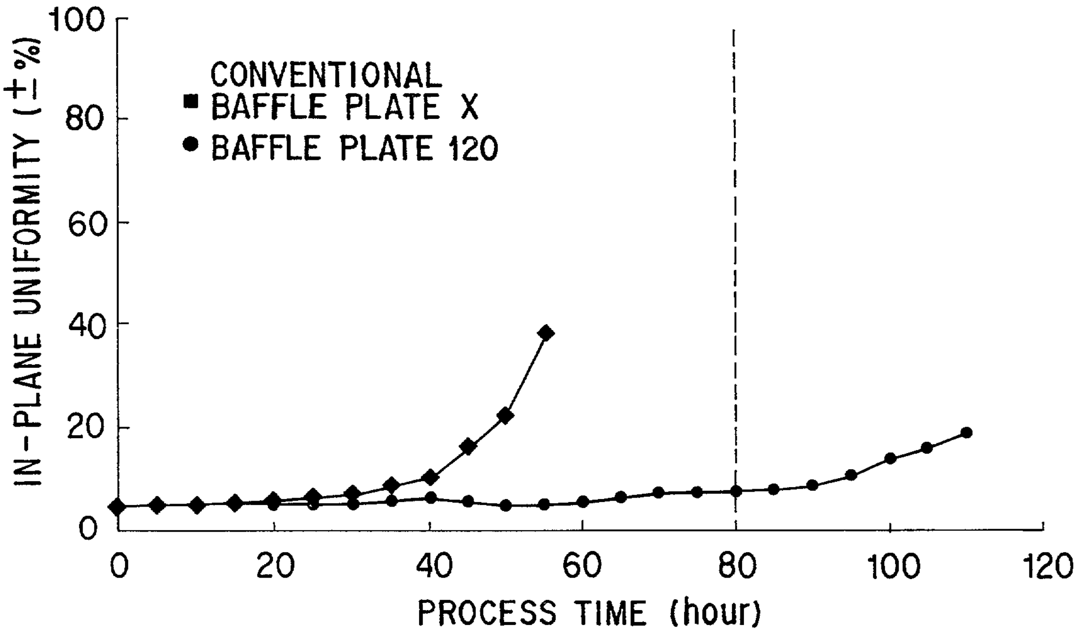
IN-PLANE UNIFORMITY (±%)
100
80
60
40
20
0
CONVENTIONAL
BAFFLE PLATE X
BAFFLE PLATE 120
0
20
40
60
80
100
120
PROCESS TIME (hour)

FIG.9

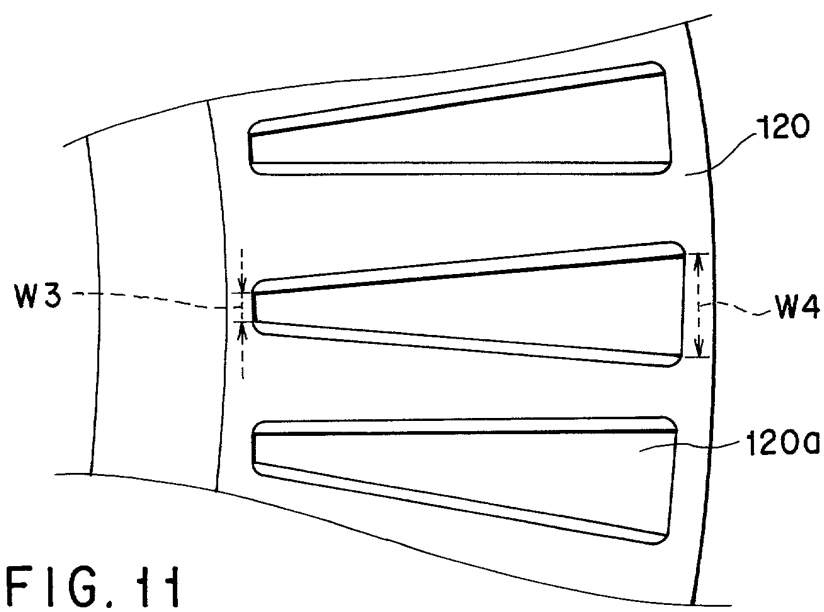
120
W3
W4
120a

FIG. 11

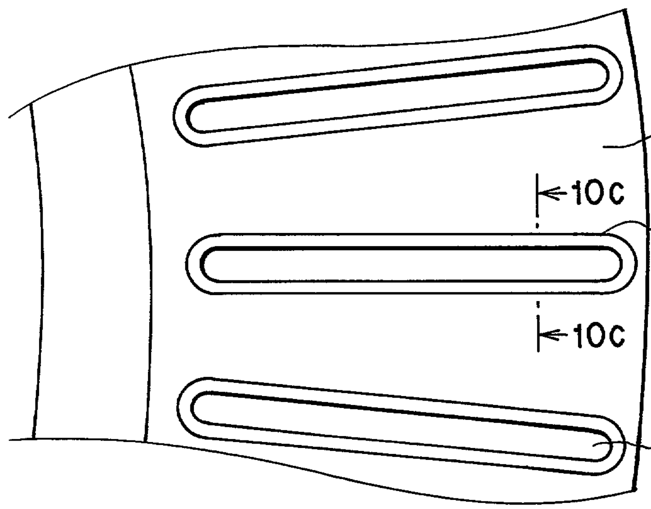

FIG. 10A

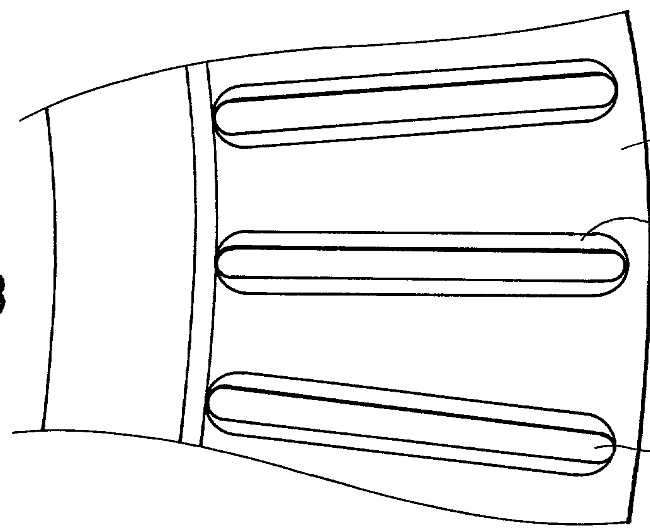

FIG. 10B

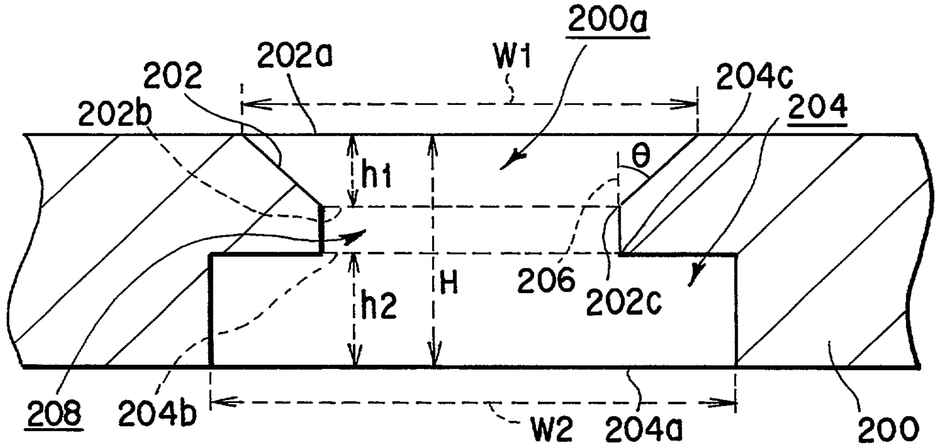

FIG. 10C

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Declaration Power of Attorney For Patent Application

特許出願宣言書及び委任状

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As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の横に記載された通りです。

My residence, post office address and citizenship are as stated below next to my name,

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

処理装置

PROCESS APPARATUS

上記発明の明細書（下記の欄で×印がついていない場合は、本書に添付）は、

The specification of which is attached hereto unless the following box is checked:

☐ ______月___日に提出され米国出願番号または特許協定条約国際出願番号を______とし、（該当する場合）______月___日に訂正されました。

☐ was filed on ______ as United States Application Number or PCT international Application Number ______ and was amended on ______ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第３７編第１条５６項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentablilty as defined in Title 37, Code of Federal Regulations, Section 1.56

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私は、合衆国法典第３５編第１１９条（ａ）－（ｄ）項又は第３６５条（ｂ）に基ずき下記の、米国以外の国の少なくとも一カ国を指定している特許協力条約３６５（ａ）項に基ずく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United states Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)
外国での先行出願

(Number)（番号）	(Country)（国名）	(Day/Month/Year Filed)（出願年月日）	Priority Not Claimed 優先権の主張なし
10-073433	JAPAN	06/03/1998	☐
10-179616	JAPAN	11/06/1998	☐
			☐
			☐
			☐

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I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.)（出願番号）	(Filing Date)（出願日）	(Application No.)（出願番号）	(Filing Date)（出願日）

私は、下記の米国法典第３５編１２０条に基いて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約３６５条（ｃ）に基ずく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第３５編１１２条第１項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第３７編１条５６項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) or 365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT Information application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which become available between the filing date of the prior application and the national or PCT international filing date of application:

(Application No.)（出願番号）	(Filing Date)（出願日）	(Status:Patented, Pending, Abandoned)（現況：特許許可済、係属中、放棄済）
PCT/JP99/01055	March 4, 1999	Pending

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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（弁理士、または代理人の氏名及び登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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Facsimile No. 213-892-5601

唯一のまたは第一発明者の氏名 杉山　智一	Full name of sole or first inventor Norikazu Sugiyama
同発明者の署名　　日付	Inventor's signature　　Date Norikazu Sugiyama　August 24, 2000
住　所 日本国東八代郡	Residence Higashiyatsushiro-gun, Japan
国　籍 日本	Citizenship JAPAN
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東京エレクトロン株式会社 知的財産部内	3-6 Akasaka 5-chome, Minato-ku, Tokyo 107-8481 Japan

（第二以降の共同発明者に対しても同様に記載し、署名をすること。）

(Supply similar information and signature for second and subsequent joint inventors.)

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第 2 共同発明者の氏名（該当する場合） 岡山　信幸	Full name of 2nd joint inventor, if any Nobuyuki Okayama
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国籍 日本	Citizenship JAPAN
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第 3 共同発明者の氏名（該当する場合） 三枝　秀仁	Full name of 3rd joint inventor, if any Hidehito Saegusa
同第 3 発明者の署名　　日付	3rd Inventor's signature Date Hidehito Saegusa　August 24, 2000
住所 日本国東八代郡	Residence Higashiyatsushiro-gun, Japan
国籍 日本	Citizenship JAPAN
郵便の宛先 〒107−8481 日本国東京都港区赤坂５丁目３番６号	Post Office Address c/o Intellectual Property Dept., TOKYO ELECTRON LIMITED
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同第 4 発明者の署名　　日付	4th Inventor's signature Date Jun Ozawa　August 24, 2000
住所 日本国中巨摩郡	Residence Nakakoma-gun, Japan
国籍 日本	Citizenship JAPAN
郵便の宛先 〒107−8481 日本国東京都港区赤坂５丁目３番６号	Post Office Address c/o Intellectual Property Dept., TOKYO ELECTRON LIMITED
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PATENT
Docket No. 28503.20058.00
Express Mail Label No. EL591115049US
Client Reference 6TM-98S1026P1

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Marco Jimenez

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the application of:

SUGIYAMA, et al.

Serial No.: To Be Assigned

Filing Date: Herewith

For: PROCESS APPARATUS

Examiner: Not Assigned

Group Art Unit: Not Assigned

ASSOCIATE POWER OF ATTORNEY

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Please recognize the following as associate attorneys in the above entitled application:

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Joseph Barrera (Reg No. 44,522)
Richard R. Batt (Reg No. 43,485)
Vincent J. Belusko (Reg No. 30,820)
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Dated: September 6, 2000

Respectfully submitted,

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